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Bone Histology of Prehistoric Inhabitants of the Canary Islands: Comparison Between El Hierro and Gran Canaria

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ABSTRACT The trabecular bone mass (TBM) of the proximal epiphyses of right tibiae belonging to 273 prehispanic inhabitants of Gran Canaria (60.81% males and 35.53% females) were assessed by histomorphometrical analysis of undecalcified samples and compared with that of 41 samples from El Hierro (52.63% males and 47.37% females). Among the prehispanic population of Gran Canaria 19.05% showed TBM values below 13.5% and 30.40% below 15%, although individual variability was high (range 6.71–35.4%). In sharp contrast with these results, only one case (2.44%) from El Hierro showed a TBM value below 15%, whereas mean TBM (23.50 ;± 5.60%) was significantly higher than that of the population of Gran Canaria (17.88 ± 5.20%). The high prevalence of osteoporosis on Gran Canaria may reflect protein-calorie malnutrition. Prehistorically Gran Canaria exhibited a relatively high population density (30–40/km^2) and a strong reliance on agriculture, in contrast with a lower population density (4/km^2) on the island El Hierro, where the population consumed mainly marine products. Am J Phys Anthropol 110:201–213, 1999.

The Canary Islands were inhabited in prehistoric times by people of north African origin, who probably arrived on the archipelago toward the middle of the first millenium BC (Navarro-Mederos,1983). Migratory movements in north Africa during the last four millennia BC were very complex and only partially known (Chamla, 1978; Dutour, 1989). It is possible that the islands were colonized by different waves of related peoples. Interestingly, prehistoric cultural remains differ from one island to another.

We have undertaken a number of anthropological studies on the prehistoric population of some of the islands of the Canary Archipelago. We have found a high prevalence of osteoporosis on Gran Canaria, in contrast with only a few cases from the western Canary Islands (González-Reimers and Arnay-de-la-Rosa ,1992). The high prevalence of osteoporosis might be attributed to malnutrition (Krane and Holick, 1994). However, the high variability of the TBM values among individuals may be related to differences in social status, although we were unable to document differences between the few cases buried in tumuli and those buried in caves.

In contrast, only two out of 17 prehistoric individuals from El Hierro and Tenerife

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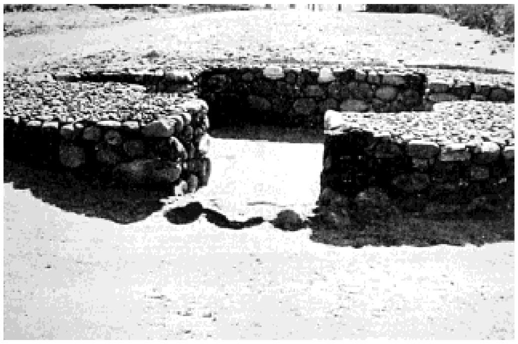

Fig. 1. Prehistoric house from Gran Canaria.

showed TBM values in the osteoporotic range (González-Reimers et al., 1991). The sample was too small to draw definitive conclusions, but the preliminary results suggest that there may be differences in bone mass and, thus, in the prevalence of osteoporosis, among the prehistoric inhabitants of the different islands of the Canary Archipelago. We suspect that the prevalence of osteoporotic disease was related to profound differences in population density and socioeconomic conditions among the different islands of the Archipelago (Figs. 1 and 2).

The goals of the present study are (1) to confirm the strikingly high prevalence of osteoporosis among the prehispanic population of Gran Canaria and to discern if there are differences between individuals buried in tumuli or in caves, between males and females, and between individuals buried in different geographical areas; (2) to compare the results obtained on the population of Gran Canaria with those obtained on a sample from El Hierro. We have chosen to focus on the right tibia because of its abundance and good preservation.

MATERIALS AND METHODS

Gran Canaria

Source and antiquity of samples. Two hundred seventy-three well-preserved right tibiae were obtained from mass burials on Gran Canaria: Guayadeque (221 cases), Andén de Tabacalete (6 cases), El Agujero (21 cases), Santa Lucía (5 cases), Dragonal (2 cases), Crusesitas (6 cases), El Cabezo (5 cases), Charquitos (2 cases), Lomo de Caserones (1 case), Montaña de Juan Tello (1 case), Tifaracas (1 case), and Solana del Pinillo (2 cases) (Fig. 3). Some of these burials (El Agujero, El Cabezo, Lomo de Caserones, Dragonal, and Crusesitas) are located in the coastal regions of the island; the others are located in the central mountains. Some of the individuals were buried in collective tumuli (El Agujero, Crusesitas, and Lomo de Caserones) which are always located in coastal regions, and the others, in caves. There are some other tumuli in Gran Canaria located in central regions, but the bone fragments are poorly preserved and are not included in this study. The archaeological site of Guayadeque is by far the most important funerary complex of Gran Canaria, with several huge collective burial caves containing remains of hundreds of individuals. Several of these caves are still not excavated.

The material analyzed in this study includes nearly 70% of the well-preserved tibiae from Guayadeque deposited in the Museo Canario, and the totality of the well-preserved tibiae of El Agujero, Lomo de Caserones, Crusesitas, El Cabezo, Tifaracás, Silva, Andén de Tabacalete, Santa Lucía, Dragonal, and Solana del Pinillo (only adults).This material belongs to the anthropological collection of the Museo Canario (Las Palmas).

Absolute dates are available for some of the remains: 875 ± 60 BP for 20 samples from El Agujero, 1740 ± 90 BP for 5 samples from El Cabezo, and 1140 ± 1000 BP for the sample from Caserones. Other figures reported for Gran Canaria yield time depths ranging from 2080 ± 60 BP to 700 ± 50 (Onrubia Pintado,1987).

Determination of sex and age. The right tibia was chosen for examination because of its abundance and its good preservation. Only tibiae belonging to adult individuals, intact enough to allow accurate length and epiphyseal width measurements, with non-eroded cortical surfaces, and without any associated pathological condition, were included. In those cases in which the complete skeleton was available, only tibiae of nonsenile individuals were included (see below).

Sex was estimated adapting Íscan and Miller-Shaivitz's method (1984) to the population of Gran Canaria. This method is based on discriminant functions performed

Fig. 2. Archaeological site "Guinea" (El Hierro island), showing thousands of shells of "Patella."

with several osteometric dimensions taken from the tibia, such as bone length, proximal and distal epiphyseal breadth, anteroposterior and transverse diameter, circumference at the nutrient foramen level, and minimum shaft circumference. We measured these parameters in 52 complete skeletons from Gran Canaria (Table 1) in which sex was determined by inspection of the pelvis, and combined these parameters by stepwise multivariate analysis, obtaining discriminant functions, the best of which allows a 100 % correct sex allocation (unpublished data). This discriminant function includes tibial length, proximal epiphyseal breadth, transverse diameter, and minimum shaft circumference. Applying this function to the remaining tibiae analyzed in this work, a total of 97 were classified as belonging to female individuals, and 166 to male ones. In 10 cases, values obtained did not allow unambiguous sexing and were not further considered.

Age at death was not determined from tibiae. However, because 44 individuals still showed the epiphyseal closure line, they were classified as "very young" (Bennett, 1984). In complete skeletons, age at death was estimated by inspection of the pubic symphysis following the method of Suchey and Brooks (1990): nine cases were "very young" (symphyseal stage I); 21 cases were "young" (symphyseal stage II); and 16 were "mature" (symphyseal phase III). Six additional cases with symphyseal phases IV, V, and VI were not selected for histomorphometrical analysis.

Six cases classified as "very young" by the presence of the tibial epiphyseal closure line were also classified as "very young" according to the inspection of the pubic symphysis. So, age at death was assessed in 84 individuals of Gran Canaria: 47 of them died at very young ages, 21 at young ages, and 16 at mature ages. Age at death could not be determined for 189 individuals.

El Hierro

Source and antiquity of samples. The island of El Hierro is the smallest of the

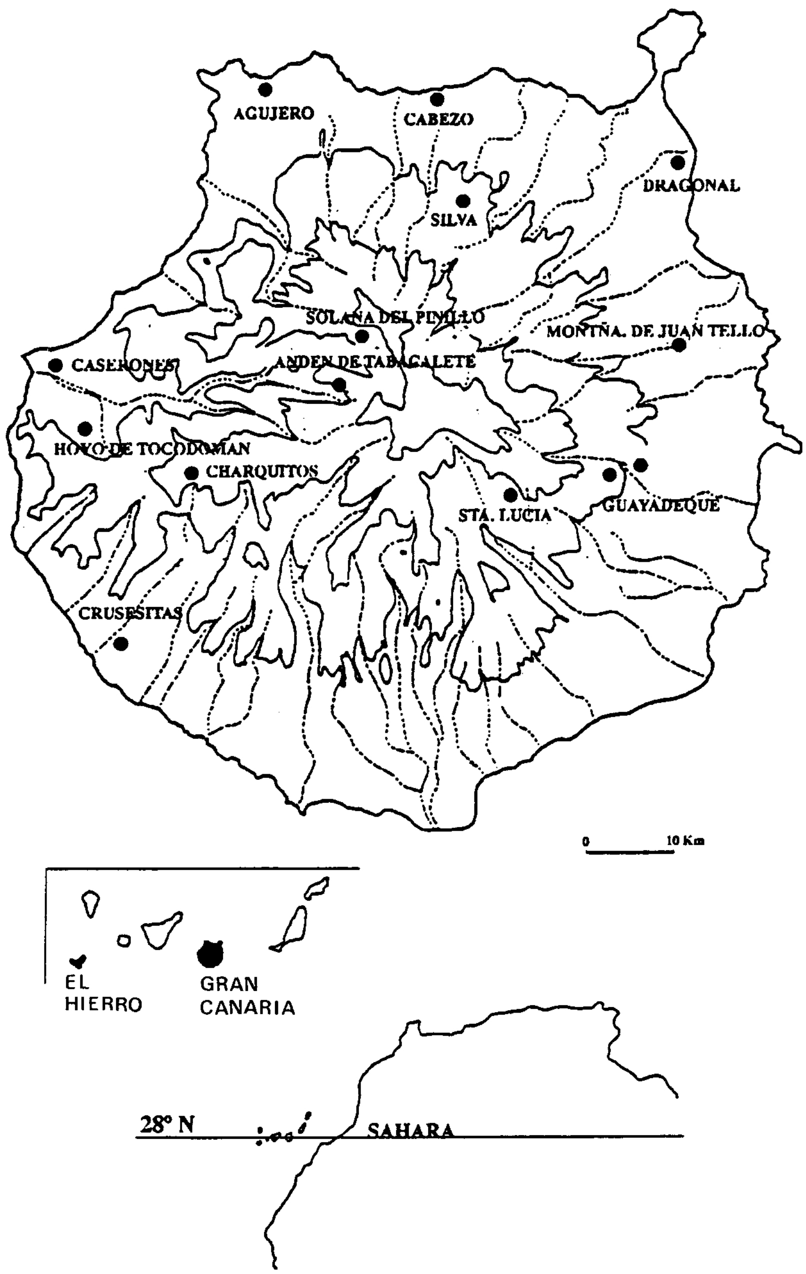

Fig. 3. Situation of the Canary Islands in front of the Northwest African coast and map of the islands Gran Canaria and El Hierro with the archaeological sites cited in the text.

seven "big" islands of the Canary Archipelago (Fig.3). It was sparsely inhabited in prehispanic times. A few collective burial caves have been found containing bare bones corresponding to either a few or several dozens individuals, without any evidence of mummification.

Absolute dates for some prehispanic remains that are not included in this study are available. The dates range between 1200 ±

TABLE 1. Mean values (in mm) of different anthropometric data[1] of the prehispanic population of Gran Canaria

	Sexed by pelves		Remaining samples	
	Males (40)	Females (12)	Males (131)	Females (86)
Tibial length	372 ± 26.9	336.2 ± 12.6	366.5 ± 18.5	335.5 ± 19
Proximal epiphyseal breadth	77.4 ± 4.3	66.8 ± 2.6	76.5 ± 2.9	66.9 ± 3.5
Anteroposterior diameter	37.1 ± 3	31.1 ± 2.1	36.8 ± 2.2	30.4 ± 2.5
Minimal circumference	78.7 ± 5	66.8 ± 3.4	79.3 ± 4	68.4 ± 3.8
Circumference at the nutrient foramen	98 ± 3.3	84.7 ± 5.4	96.7 ± 6.8	82.4 ± 5.1
Transverse diameter	25.7 ± 1.7	20.1 ± 1.4	24.2 ± 1.7	20.5 ± 1.5

[1] Five males and one female sexed by pelves were not included in the histomorphometrical analysis.

60 BP and 1050 ± 60 BP (Onrubia Pintado, 1985).

Determination of sex and age. We have analyzed 41 right tibiae of El Hierro, all of them belonging to the archaeological site of Punta Azul. This site, which is located in the southern coast of the island, is, by far, the most important prehispanic cemetery of El Hierro, and contains the remains of more than 100 individuals. The same discriminant function performed with the skeletons from Gran Canaria was applied to the population of El Hierro: 20 were males, 18 females and in 3 cases, results were inconclusive. Anthropometric measurements, assuming a correct sex allocation, show that the prehispanic population of El Hierro had shorter tibial length than the population of Gran Canaria, but similar proximal epiphyseal breadth, anteroposterior diameter, transverse breadth, and circumference at the foramen level. Distal epiphyses were significantly broader in males, who also showed thicker minimum shaft circumference than that of the males from Gran Canaria.

Only one individual still showed the epiphyseal closure line. Age at death was determined by inspection of the pubic symphysis (Suchey and Brooks, 1990). Most individuals died before age 53 (phase III).

Bone Histomorphometry

A small portion of the medial part of the posterior aspect of the proximal epiphysis was removed and processed for undecalcified bone sample analysis (Fig.4). Briefly, samples were embedded in methylmethacrylate (Sigma Chemicals, St Louis, MO), stored during 24 hr at 4°C, and later polymerized at 32–34°C for 3–4 days. Embedded samples were then cut in 9–12 µm thick slices with a Reichert-Jung microtome so that the resulting sections were perpendicular to the long axis of the tibiae; slice were stained with toluidine blue. TBM was determined using an image analyzer equipped with the program Image Measure 4.4a (Microscience Inc.) at 40×. Results are given as % of total area.

Fig. 4. Right tibia from Gran Canaria, showing the exact location from which the samples were obtained.

We compared TBM of the prehispanic population with that of our own control group, which consists of 12 modern individuals aged 17–44 years, from whom a bone specimen was obtained from tibiae during

TABLE 2. Normal values of trabecular bone mass (as %) in modern populations[1]

Author	Age period (years) 20–29 n	X ± SD	30–39 n	X ± SD	40–49 n	X ± SD	50–59 n	X ± SD
Merz (1969)	16	22.8 ± 4.5	19	22.1 ± 4.1	17	21 ± 4	23	19.6 ± 4.2
Meunier (1972)	28	21.7 ± 4.4	20	19.8 ± 4.8	24	19.9 ± 3.9	19	18.5 ± 4.8
Bordier (1969)	—	—	9	23.5 ± 2.3	10	21.2 ± 3.1	17	18.3 ± 3.4
Our group (tibiae)	6	24.4 ± 2.0	2	21.8 ± 1.6	2	29.9 ± 13	—	—
Our group (pelves)	5	26.1 ± 2.4	5	22.9 ± 3.6	2	21.3 ± 0.8	3	20.6 ± 6.3
Mellish males (1987)	—	—	5	22.4 ± 5.6	—	—	—	—
Mellish females (1987)	—	—	9	26.9 ± 3.9	—	—	10	22.4 ± 5.4
Ballanti females range (1990)	3	26.9 25.3–29.1	5	23.8 21.1–25.3	5	19.7 18–22.6	5	19.6 15.5–23.6
Ballanti males range (1990)	7	22.6 19.6–26.6	4	23.2 21.2–29	8	20.7 16.4–24.8	10	22 17.2–25

[1] Unless otherwise specified, data belong to iliac crest.

surgical operations on the right knee. We have also used, as reference values, those derived from iliac crest specimens of 16 individuals aged 16–49 years who died in the Intensive Care Unit of our Hospital (Hospital Universitario de Canarias, Tenerife) of injuries from traffic accidents and were selected as kidney donors. We also used data reported by several investigators (Merz and Schenk, 1969; Meunier et al., 1972; Bordier and Tun Chot, 1969; Courpron et al., 1971; Croucher et al., 1994; Mellish et al., 1987; Dahl et al., 1988; Ballanti et al., 1990). Some of these results are shown in Table 2. We approximated the mean lower limit of the 95% confidence interval of normal TBM values. The "approximate mean" is 13.5%. This value defines severe osteoporosis in this study. The approximate mean lower limit of the 90% confidence interval (mean,1.64 standard deviation) of normal TBM is 15%. This figure defines moderate osteoporosis.

Statistical Analysis

We assessed differences of quantitative parameters between four sets of two groups (male/females, tumuli/caves, coast/central mountains; El Hierro/Gran Canaria) by Students t test. Differences in TBM among the three age groups identified were assessed with variance analysis. The effects sex, island, and age on TBM and the interaction between these factors were determined with two-way variance analysis. Because only one "age" is available for the samples from El Hierro, we analyzed the sex and island separately, and sex and age only in the sample from Gran Canaria. Stepwise logistic regression analysis was performed to determine the relative and hierarchical weight of the parameters sex and age at death in the diagnosis of (1) severe osteoporosis (TBM <13.5%) and (2) moderate or severe osteoporosis (TBM <15%).

RESULTS

Male and female values of TBM are shown in Figure 5 and Table 3. The mean TBM value of the prehispanic sample of Gran Canaria was 17.88 ± 5.20 %, which is significantly lower than the mean value observed in the control population (24.58 < 5.30 %, $t = 4.37$, $p < 0.001$). Differences are still significant if we compare TBM of the control group with that of very young prehispanic individuals (20.19 ± 4.81%, $t = 2.77$, $p < 0.01$). However, there were differences in TBM between the very young, young and mature individuals ($F = 11.5$, $p < 0.0001$, Table 3). In Table 3, we also show TBM values of the population with unknown age at death; no differences exist between TBM of these individuals and those with known age at death.

The mean TBM of the males (18.55 ± 4.98%) was significantly higher than that of the females (17 ± 5.11%, $t = 2.41$, $p = 0.016$). No differences were observed between individuals buried either in the coastal regions or in the central mountains, nor between those buried in tumuli and in caves.

Eighty-three out of the 273 individuals (30.40%) showed TBM values under 15%,

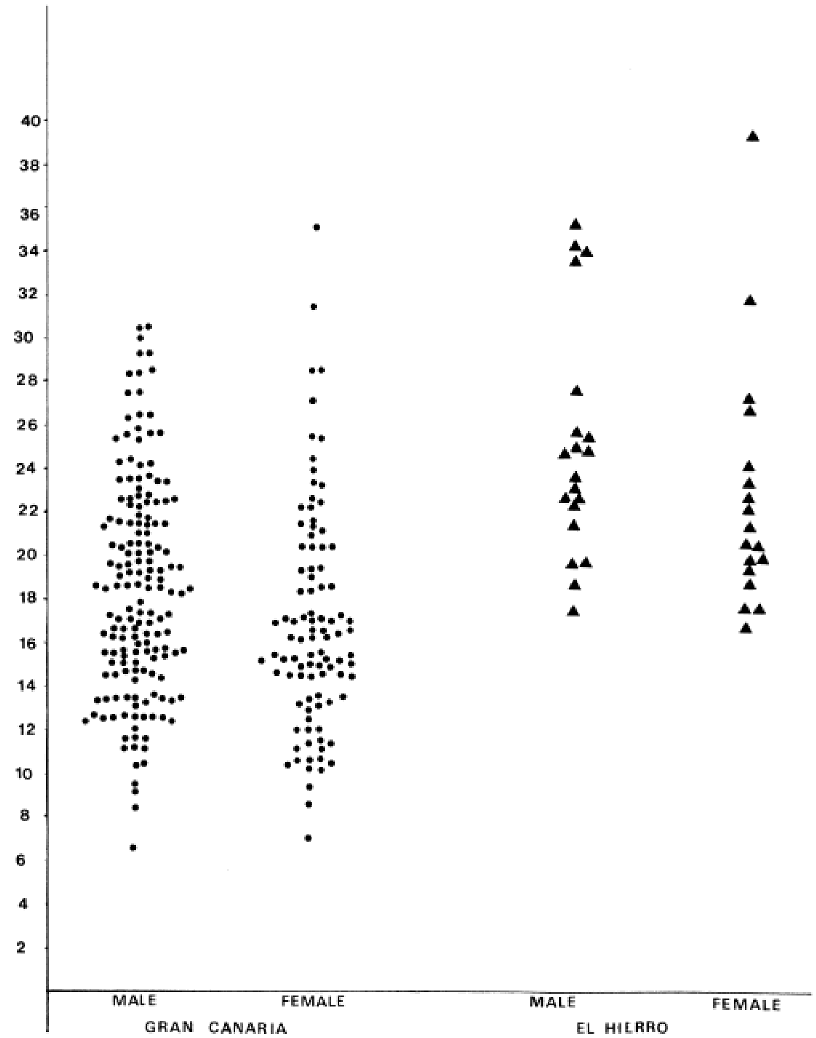

Fig. 5. Individual values of TBM of males and females of El Hierro and Gran Canaria.

whereas 52 (19.05%) showed TBM values under 13.5%. These figures reached 19.15% and 8.51%, respectively, when only the very young individuals are considered; 33.33% and 19.05%, respectively, among the young individuals, and 62.50% and 50% among the mature ones. In 30.16% of those with unknown age at death, TBM values were under 15% and in18.52% the values were under 13.5%.

In the sample from Gran Canaria only age at death exerts an independent effect on TBM (F = 3.8, p = 0.028). Sex has no statistically significant effect (F = 1.81, p = 0.18). No interaction exists between sex and age at death regarding TBM (Table 4).

Logistic regression analysis (Table 5) also shows that age at death is the main factor related to TBM. Death at mature age is associated both with severe [relative risk (RR) = 6.35, p = 0.0041] and moderate or severe (RR = 6.12, p = 0.0041) osteoporosis. Death at young or mature age is also related to the presence of both severe (RR = 3.25, p = 0.0172) and moderate or severe osteoporosis (RR = 3.92, p = 0.0124). Female sex is

TABLE 3. Trabecular bone mass of the prehispanic sample of Gran Canaria by age and sex

	Males (M)		Females (F)		Total (M + F + U[1])	
	n	X ± SD	*n*	X ± SD	*n*	X ± SD
Very young (group 1)	32	21.2 ± 4.3	14	18.1 ± 5.5	47	20.2 ± 4.8
Young (group 2)	17	17.9 ± 5.7	3	15.6 ± 1.3	21	17.3 ± 5.3
Mature (group 3)	9	14.0 ± 4.3	5	14.7 ± 6.7	16	13.3 ± 5.3
F value 11.52		9.08		0.78		
P value <0.0001		0.0004		>0.1		
Differences between groups		1 vs. 2,3		—		
1 vs. 2,3 (SNK test)		2 vs 3				
2 vs 3						
Known age at death	58	19.1 ± 5.3	22	17.0 ± 5.5	84	18.2 ± 5.6
Age at death unknown	108	18.3 ± 4.8	75	17.0 ± 5.0	189	17.6 ± 4.9

[1] U = undefined sex.

TABLE 4. Combined effects of sex and age at death on trabecular bone mass (two-way variance analysis)

	F	Significance
Main effects	3.126	0.031
Sex	1.808	0.188
Age at death	3.785	0.028
Two-way interactions	1.943	0.151

TABLE 5. Logistic regression analysis between osteoporosis, age at death, and sex

	Relative risk to suffer	
	Moderate or severe osteoporosis	Severe osteoporosis
Death at young or mature age	RR[1] = 3.92 95% CI = 1.34–11.06 p = 0.0124	RR = 3.25 95% CI = 1.20–5.54 p = 0.0172
Females sex	RR = 3.27 95% CI = 1.07–10 p = 0.0373	—
Death at mature age	RR = 6.12 95% CI = 1.78–21.05 p = 0.0041	RR = 6.35 95% CI = 1.79–22.37 p = 0.0041

[1] RR = relative risk; CI = confidence interval.

TABLE 6. Two-way variance analysis between the parameters trabecular bone mass, sex and island (El Hierro or Gran Canaria)

	F	Significance
Main effects	25.299	0.000
Sex	5.129	0.024
Island	45.469	0.000
2-way interactions	0.140	0.708

also related this last parameter when dead at young and mature age are considered together ($RR = 3.27$, $p = 0.0373$).

The mean TBM value of the population of El Hierro was 23.50 ± 5.60%, similar to that of the control group, but significantly higher than that found in the Gran Canaria population ($t = 6.44$, $p < 0.001$). Differences between the two islands are statistically significant when either the males ($t = 5.37$) or the females are compared ($t = 4.27$, $p < 0.001$ in both cases). However, differences between sexes are not statistically significant among the sample from El Hierro, although males showed slightly higher absolute TBM values (24.94 ± 5.38%) than females (22.70 ±5.68%, $t = 1.25$). TBM was below 15 ± 14.12%) only in one case (of undefined sex).

Both parameters "sex" ($F = 5.13$, $p = 0.024$) and "island" ($F = 45.47$, $p < 0.001$) exert significant independent effects on TBM; no interactions exist between both parameters (Table 6).

DISCUSSION

Histomorphometrical analysis of cancellous bone samples is the gold standard for the diagnosis of osteoporosis (González-Macías and Serrano,1992). Osteoporosis is defined by a reduction in the mass of bone per unit volume (Glaser and Kaplan,1977; Krane and Holick,1994). Bone mass peaks at about age 30-–35 for cortical bone, and it decreases physiologically thereafter. Therefore, several authors use the term osteopenia to refer to decreased bone mass, and reserve the term osteoporosis to those situations in which osteopenia leads to clinical manifestations (bone fracture) (Gillespy and Gillespy, 1991) and/or it is excessive after correction for age and sex.

In this study, we have found a high prevalence of osteoporosis among the prehispanic population of Gran Canaria, in striking contrast with the results obtained on the sample of El Hierro.

Several authors have examined bone mass and bone loss in archaeological populations from different regions, either by noninvasive methods, such as photon absorptiometry and radiology, or by invasive ones (Agarwal and Grynpas,1996; Mulhern and Van Gerven, 1997). In most of these studies, the finding of osteoporosis has been related to nutritional disorders (Eriksen,1976; Dewey et al., 1969; Martin et al.,1985).

For any individual, bone mass is a combination of peak bone density and subsequent bone loss. Both parameters are influenced by genetic, hormonal, and environmental factors (Center and Eisman, 1997; Matkovic,1996). Peak bone mass is achieved during the first three decades of life (Vaananen, 1991).In our study, at least 47 individuals died before 25 , i.e., before having reached the peak bone mass. Although TBM of this group was higher than the values obtained in the other age groups, still an important proportion of them did show moderate or severe osteoporosis, and, as a whole, they showed significantly less TBM than the modern controls (which also include some very young individuals).

Besides genetics, peak bone mass is influenced by dietary factors and physical activity (Eriksen and Langdahl, 1997). Among dietary factors, calcium intake during growth is related to bone mass, a fact which is supported both by clinical (Ilich et al.,1998; Tsukahara et al., 1997) and experimental (Talbott et al., 1998) studies. Also, in recent times, and in contrast with former studies (Reed et al., 1994), it has been reported that vegetarians show lower values of bone mineral density (or less increase with time) than nonvegetarians, both in premenopausal (Barr et al.,1998) and postmenopausal (Lau et al., 1998) women. The same is valid for people consuming macrobiotic diets (Parsons et al., 1997). Excess dietary fat inhibits calcium absorption and may adversely affect bone mass (Wohl et al., 1998). Regarding protein, it is clear that either protein (Stewart, 1968) or protein-calorie malnutrition (Platt and Stewart, 1962) adversely affects bone development and bone mass. The deleterious effect of a high protein diet is less clear, although a high protein diet increases calcium excretion (Itoh et al., 1998). Some authors report increased risk of forearm fracture with high protein consumption (Feskanich et al., 1996); others find a direct correlation between protein intake and bone mass (Cooper et al., 1996). The calciuric effect of excess protein may be counteracted by an adequate calcium intake (Heaney,1998).

Bone mass slowly decreases after the third–fourth decade, so osteoporosis is common in elderly individuals. The low TBM values herein reported for the population of Gran Canaria cannot be explained by old age. Although bone mass clearly declines with age, the prevalence of severe and moderate osteoporosis is high in the group of 84 individuals for which age at death was determined, even in the youngest ones. With respect to the other 189 individuals, although perhaps there is a higher proportion of older ones among them (since those with the epiphyseal closure line still evident are not included in this group), the prevalence of osteoporosis and the mean TBM are similar to the figures observed in the group with known age at death.

As expected, older individuals showed significantly less TBM values than the younger ones. Age is the main factor influencing TBM among the population of Gran Canaria. This confirms, on histological grounds in a prehistoric sample, that age surely plays a role in bone loss, as other authors have reported (Dewey et al.,1969; Eriksen,1976). However, it does seem that the high prevalence of osteoporosis among the prehispanic inhabitants of Gran Canaria cannot be solely attributed to age, because osteoporosis is highly prevalent also among the younger individuals.

Besides age, there are many conditions associated with osteoporosis, including some relatively common diseases, as diabetes (Krane and Holick, 1994). However, in our geographical area, prevalence of these entities, including diabetes, is about 2–3% (Figuerola,1992). Thus, the high prevalence of osteoporosis observed in the sample of

Gran Canaria cannot be attributed to these associated diseases.

Among the samples of El Hierro, only one case still showed the epiphyseal closure line, i.e., the population analyzed is probably older than that of Gran Canaria, or, at least, the proportion of young people is smaller in El Hierro than in Gran Canaria. Notwithstanding this fact, mean TBM of the population of El Hierro is higher (23.50 ± 5.60%) than that of the young people of Gran Canaria (20.19 ± 4.81 %; $t = 2.95$, $p < 0.005$).

The high prevalence of osteoporosis in Gran Canaria and the differences between the two islands are difficult to explain. It is very hard to believe that diseases commonly associated with osteoporosis would affect, in the worst of the cases, more than 4–5% of the population. Furthermore, there is no reason why they would affect only the population of Gran Canaria and not that of El Hierro. On the other hand, besides age and disease, bone mass is influenced by nutrition, physical activity, and genetics.

Physical activity associated with mechanical loading (Courteix et al., 1988) exerts an important influence on bone mass, in children (Slemenda et al.,1991), adolescents (Boot et al., 1997), and adults (Smith and Gilligan, 1991; Recker et al., 1992). Tibiae are strongly subjected to mechanical loading, so different patterns in activity may explain, in part, the differences between the two islands. In this sense, lumbar vertebrae of Punta Azul shows signs of intense osteoarthritis (Arnay-de-la-Rosa et al., 1996), which is not present among the population of Gran Canaria. One possible explanation is that physical activity (related with loading) was higher among the inhabitants of El Hierro, causing osteoarthritis and preserving bone mass, although the exact nature of what was loaded remains speculative.

Genetic factors may also play a role in bone mass (Johnston and Slemenda,1995; Garabedian,1995). The Canary Islands were inhabited in prehistoric times by people arriving from north Africa. Differences in pottery and other archaeological artifacts, as well as in social structure and inhumation ritual are striking between the different islands of the Archipelago. Although the population of each island should have been related to that of the other islands, some differences do exist between them. In this study, it is apparent that the tibiae from El Hierro are shorter than those from Gran Canaria, but they are considerably thicker than those of Gran Canaria. Although leg length has been considered an indicator of malnutrition during childhood (Gunnell et al., 1998), perhaps the shorter and thicker tibiae of the inhabitants of El Hierro do not indicate malnutrition, but some "racial" differences with the population of Gran Canaria. Perhaps these differences also account for differences in TBM.

TBM of the people of Gran Canaria, is, however, strikingly low. As noted earlier, protein-calorie malnutrition may lead to osteoporosis. The "nutritional hypothesis" has been widely used to explain the finding of a high proportion of osteoporosis, both in ancient (Martin et al.,1985; Eaton and Nelson,1991) and modern (Gupta,1996) population groups.

There are some theoretical data that support the hypothesis that a strong reliance on cereal grain together with episodic malnutrition among the prehispanic people of Gran Canaria may explain, at least in part, the high prevalence of osteoporosis observed. In this sense it is important to keep in mind the following:

1. The island of Gran Canaria was densely populated in prehispanic times (Torriani, 1977).
2. Archaeological remains point to a strong reliance on cereal-based agriculture (Jiménez Gómez, 1979), with several silos located in easily defensible places (Fig.6).
3. The climate of the island, situated near the Sahara Desert, includes marked variations in yearly rainfall, a fact that has influenced agricultural production even in recent times. Moreover, locust plagues coming from the African Sahel, the last one in the late 1950s, also have devastating effects.

In contrast,

1. The island of El Hierro was scarcely inhabited.

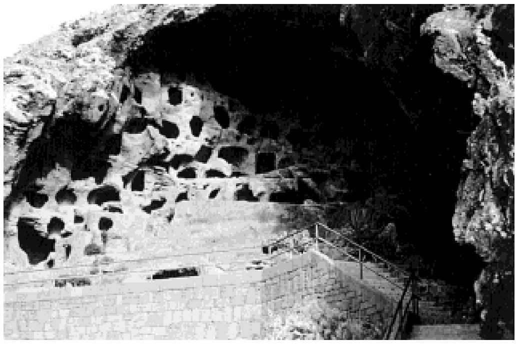

Fig. 6. Collective silos ("Cueva del Rey," Tejeda, Gran Canaria).

2. Subsistence was mainly based on consumption of marine products and goat-herding and sheep-herding (Jiménez Gómez, 1993); the influence of climatic variations on this kind of economy is small.

Thus, it is likely that, in Gran Canaria, the fragile equilibrium between agriculture production and population needs became broken in years of scarce rainfall and/or other catastrophic events. The prehispanic inhabitants, aware of this possibility, built the huge silos in easily defensible areas, probably to store the surplus obtained in the "good" agricultural years. Indeed, chroniclers wrote that the people had to give the tenth part of all the fruits to the lord of the land, who stored it and distributed it among the population in the years of bad yield (Morales-Padrón,1994). Chroniclers also described a system of ranked status and some measures to control population increase, such as female infanticide, except for those girls born in the first delivery, in order to balance the lack of resources (Abreu Galindo,1977).

Thus, both archaeological data and chroniclers' writings support the interpretation that the high prevalence of osteoporosis in Gran Canaria may have been due to widespread periodic protein-calorie malnutrition.

However, although mean TBM values are low, with many individuals in the osteoporotic range, individual TBM values show a high variability: indeed, there are a number of cases in which TBM reaches figures higher than 25%. These results could be attributed to social differences. Although we are unable to define which individuals belonged to the dominant social class, our data show clear-cut individual differences in TBM values in the population studied, in agreement with previous results (González-Reimers and Arnay-de-la-Rosa,1992).The possibility exists that there was different availability of food to individuals belonging to different social classes, or individual differences could be explained by differences in physical activity. The latter may explain the differences between men and women in Gran Canaria, although, as in men (Fig. 5), marked differences also exist in individual TBM values among the women. Chroniclers wrote that some women "belonging to the high social class" (called "harimaguadas") received special care and extra food during childbearing age in order to assure fertility. It is possible that some of the tibiae with high TBM values belong to these women, but this assertion is speculative.

The same reasoning applies when explaining the differences observed among the population of El Hierro, although the samples analyzed belong to the same burial site. Chroniclers did not write about different social classes in the prehispanic society of El Hierro.

Diachronic variability could perhaps contribute to the differences observed; we know absolute dates of only a few (27) of the tibiae herein studied, and all of them are from Gran Canaria. The figures range from 875 BP to 1740 BP. The mean TBM of the most recent individuals (those buried in the central tumulus of El Agujero) seems slightly higher (18.87 $\pm$ 6.35 %) than that of the most ancient ones (15.57 $\pm$ 4.9 %); however, this difference is not statistically significant (t = 1.24, $p < 0.1$). The islands have probably been inhabited for 2500 years, and some of the samples are much older than others. It is possible that during the 20 centuries between the arrival of the first islanders and the Spanish conquest, socioeconomic conditions fluctuated from time to time. We have no written record of the actual conditions because only chroniclers who arrived with the Spanish conquerors,

or, in the best of the cases, some decades before, wrote about the prehispanic society of Gran Canaria or El Hierro. Archaeological data do not support the existence of diachronic differences.

In conclusion, we have observed a high prevalence of osteoporosis in a relatively large sample of prehispanic individuals of Gran Canaria, in striking contrast with the data obtained on a sample from the island of El Hierro. These results may reflect differences in food availability between the densely populated Gran Canaria and El Hierro. The economy of Gran Canaria was based on agriculture, which was subject to climatic irregularities. The island of El Hierro, however, was sparsely inhabited, and local economy was based on goat herding and shellfishing. Possibly, different degrees of physical activity between the populations of the two islands also contributed to the observed differences in TBM.

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